

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Combined Ultraviolet Studies of Astronomical Sources

NASA Grant NAG5-87

Semiannual Progress Report No. 9

For the Period 1 August 1984 through 31 January 1985

Principal Investigators

Drs. A. K. Dupree; S. L. Baliunas; W. P. Blair;
L. W. Hartmann; J. P. Huchra; J. C. Raymond;
G. H. Smith; D. R. Soderblom

February 1985

Prepared for
National Aeronautics and Space Administration
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138



The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this Grant is Dr. Yoji Kondo
Code 683, Laboratory for Astronomy and Solar Physics
Goddard Space Flight Center, Greenbelt, MD 20771

Combined Ultraviolet Studies of Astronomical Sources

NASA Grant NAG5-87

Semiannual Progress Report No. 9

For the Period 1 August 1984 through 31 January 1985

Principal Investigators

Drs. A. K. Dupree; S. L. Baliunas; W. P. Blair;
L. W. Hartmann; J. P. Huchra; J. C. Raymond;
G. H. Smith; D. R. Soderblom

February 1985

Prepared for
National Aeronautics and Space Administration
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory is a member of the Harvard-Smithsonian Center for Astrophysics
--

The NASA Technical Officer for this Grant is Dr. Yoji Kondo
Code 683, Laboratory for Astronomy and Solar Physics
Goddard Space Flight Center, Greenbelt, MD 20771

Cygnus Loop

Three positions were observed; Miller's position 3 in High Dispersion, and two positions along the Hester, Parker and Dufour "spur" at Low Resolution. We confirm the hypothesis that resonant scattering within SNR filaments decreases the intensity of the C IV lines (Raymond et al., Ap. J., 246, 100). We find that the 'spur' shows less complete cooling and recombination toward its tip as predicted by Hester, Parker and Dufour, but we also find that the shock velocity is higher near the tip, complicating the interpretation of an interstellar cloud struck by the supernova blast wave. Both high and low dispersion optical observations of the IUE positions have been reduced, and we have found the explanation for the 'non-thermal' velocity broadening observed in the Cygnus Loop and the old supernova remnants.

Oxygen-Rich Supernova Remnants

High particle background limited the exposure on 1E0102-72 to 5 hours. Even so, broad C IV emission was detected, and the O IV]-Si IV blend at 1400\AA and the O III] $\lambda 1664$ line may have been detected as well. We are applying for time for combined ESA-NASA long exposure with J. Danziger in the next round.

LMC Supernova Remnants

Observations are not yet complete. We expect to observe N49 in February.

P Cygni Profiles in Dwarf Novae

IUE observations of HL Cma were obtained December 28-30, with simultaneous optical coverage December 29-30. We now have good coverage through the orbital period and through outburst maximum and decline. C. Mauche is extending the profile model calculations reported at the Sixth Year IUE conference (J.

Raymond, p. 301). We find that the wind must be very strongly clumped, perhaps by shocks like those believed to account for O star X-ray emission. The wind must originate in the disk or accelerate very slowly if it originates near the dwarf.

Soft X-ray Photoionization of Interstellar Gas

Observation scheduled for February 27.

Spectral Variations in AM Her Stars

H0139-68 was observed through 5 orbital cycles on December 27. The data have been reduced, but the analysis is not yet complete. AM Her was observed about halfway between its maximum and minimum \dot{M} states.

The Mass of Feige 24

The one exposure obtained so far implies a mass above $0.6 M_{\odot}$. The second exposure, which will tie down the mass estimate, will be obtained February 3. Further optical observations were obtained December 29.

Atmospheric Inhomogeneities in Lambda Andromedae and FF Aquarii

In the chromospherically active G8 III-IV star Lambda And, the ultraviolet emission was sampled as part of an ongoing project to study the ultraviolet emission during the star's six year magnetic activity cycle. Our IUE spectra of Lambda And revealed the most energetic stellar flare and the first on a giant star observed in the ultraviolet (Baliunas et al. 1984). In the binary FF Aqr, the subdwarf O-type star was used to probe the atmosphere of its companion G8 III star during eclipse egress and ingress. Enhanced absorption in the spectrum lines of the subdwarf at phases just past emersion indicates an extended

atmosphere well above the limb of the giant star. A small flare is present in the archival spectra of FF Aqr, and analysis of the flare is in progress. One remaining shift is scheduled for February 1985.

Photometric and Spectroscopic Observations of Capella

Our recent photoelectric photometry of Capella (G5 III + F9 III) confirms the results of earlier photometric studies suggesting that the star is variable in light. Capella has been classified as an RS CVn variable, showing as it does bright chromospheric and coronal emission in addition to visible light modulation. The photometric brightness of Capella, however, appears to be correlated with increasing net H α emission strength. This behavior is unlike "starspot" phenomena reported for the RS CVn binaries which show photometric faintness associated with increased chromospheric emission, presumably caused by visible darker spots with bright ultraviolet emissions from the spots and associated active regions. We plan to reanalyze extant ultraviolet spectra in light of our visible photometry as well as our new determination of the rotation rates of the stars. We are awaiting delivery of archival spectra for analysis.

α Ori

Betelgeuse (Alpha Ori - M2Iab) was the object of frequent monitoring during 1984. Since it is so bright, observations of high precision are possible and variability is present on different time scales. The 1984-85 observing season is particularly attractive for observations because it represents a time near maximum luminosity and minimum radial velocity. An intensive multifrequency observing program was begun during the Seventh Round of the IUE Observing program. Results from the first two months of 1984 have been published (Dupree,

Sonneborn, Baliunas, Guinan, Hartmann, and Hayes 1985). Those observations, in conjunction with archival data, show that there is clear evidence for chromospheric variability. The Mg II fluxes do not appear to match the long term optical variations, but a shift of the optical ephemeris by six months improves the correlation. If confirmed, such a shift suggests that the chromospheric enhancement is displaced to follow and hence may result from the maximum in photospheric luminosity.

Red Giants

The observations of metal-deficient red giant stars in the field have been completed during this report period. Four LWP exposures of 3 stars were taken during our 4 shifts: HD 135148 and BD-18271 at low dispersion and 2 high dispersion images of HD 6833. The low dispersion spectra show no sign of Mg absorption or emission near the magnesium resonance lines at $\lambda 2800$. This is generally interpreted as a filled-in absorption feature denoting the presence of chromospheric emission. The high dispersion spectrum of HD 6833 shows evidence for an asymmetric emission line in the sense of violet < red implying the presence of a stellar wind. This is particularly interesting because our Ca II spectra of the K line show no indication of outflow. This confirms our understanding from semi-empirical modeling that the magnesium transition is a more sensitive diagnostic of mass outflow. A paper is in preparation.

M67 Giants

Ken James and Graeme Smith had two IUE shifts for this project in October 1984 and both were successful. One spectrum was obtained on each shift with the LWP camera at low resolution. The target stars were two of the brightest red giants in M67, and both showed Mg II emission. This is the oldest open cluster in which IUE has been used to obtain ultraviolet spectra. Based on these observations, in the future we should be able to observe additional stars at fainter magnitude. We are also in the process of obtaining spectra of the Ca II K line with ground-based telescopes. One of our targets has a strong asymmetric Ca II emission core.

High-Velocity Winds from Hybrid Stars

A paper entitled "On the Outer Atmospheres of Hybrid Stars" by Hartmann, Jordan, Brown, and Dupree has been submitted to the Astrophysical Journal. In this paper we confirm that ϵ Aur and θ Her are hybrid stars, as suggested by Reimers, and show that γ Aql is still another member of the class. High-dispersion observations of the hybrid star α TrA confirm the large widths of the C IV emission lines, and provide a measurement of the electron density from the C II lines near 2325 angstroms. The emission line fluxes are used to derive emission measure distributions; assuming the density derived for α TrA is characteristic of all the hybrid stars, we explore some simple atmospheric models. The gas at temperatures of 2×10^5 K probably has a scale height that is an appreciable fraction of the stellar radius. The Si III] and C III] line widths are probably dominated by turbulent broadening rather than expansion; the magnitude of this broadening is such that turbulent motions, rather than thermal gas pressure, probably determines the extension of the outer envelope.

Observations of the Mg II resonance line profiles show that the winds from the hybrid stars vary on timescales of a year or less. Very deep exposures of Mg II in α TrA show visible wind absorption extending out to 180 km s^{-1} relative to the photosphere. These data suggest that high-velocity mass loss is more common than previously realized.

Accretion Disk Parameters in Cataclysmic Variables - CVGWB

Four of the five observing shifts designated for this program have been used with the remaining shift scheduled for March. The intent of the program is to obtain long exposures on faint cataclysmic variables. The four shifts to date have been moderately successful, but the long exposures have had to be shortened in each case because of intolerably high background at the end of the US1 shift. SWP images have been obtained for five objects from our target list (VZ Scl, SW UMa, WW Ceti, BV Cen and AQ Eri) and the data are in the process of being reduced and analyzed.

Chromospheric Emission of Late-Type Dwarfs in Visual Binaries - LDGDS

Data acquisition was recently completed for this program to compare Mg II emission levels in pairs of stars in visual binaries. Since these pairs are coeval, these observations enable isochrones to be defined, even if the absolute ages of the systems are uncertain.

The indication so far is that the later-type, less massive star of the pair tends to have more chromospheric activity than the primary, more than stars of the same mass that are in clusters. There is no obvious explanation for this excess emission, but the picture may become clearer as the last data are reduced.

Chromospheres and Transition Regions of Stars in the Ursa Major Group - CCGDS

Some observations have yet to be made, but most of the data are in hand. The purpose of this project was to study some very young, nearby, solar-type stars, and to see to what extent purely kinematic criteria are suitable for picking out stars in the field that have a common origin.

The net result is that kinematics alone are not sufficient to select Ursa Major Group members. This is important because the Ursa Major Group is much better defined kinematically than most of Eggen's groups. The implication is that something like the Hyades Group, which is near the Local Standard of Rest in velocity space, is heavily contaminated by interlopers, and that much of Eggen's discussion of the Hyades Group is irrelevant.

A paper incorporating this and earlier IUE data, as well as some recently determined astrometry, is in preparation with B. Jones of Lick Observatory.

Blue Galaxies

We observed BSO 234, Mk309 and Mk66 in the winter of this year. We detected all three galaxies; Mk309 had a featureless continuum, we see strong Ly α in Mk66 and weak, probably extended, Ly α emission in BSO 234.

PUBLICATIONS

- Baliunas, S. L., Guinan, E. F. and Dupree, A. K. "Ultraviolet Flare on Lambda Andromedae", 1984, Ap. J., 282, 733.
- Baliunas, S. L. and Raymond, J. C. "Ultraviolet and Visible Flare on EQ Pegasi B", 1984, Ap. J., 282, 728.
- Baliunas, S. L. "Outer Atmospheres of Cool Stars Observed with IUE", invited review, Future of Ultraviolet Astronomy Based on Six Years of IUE Research, 1984, NASA Conf. Publ. 2349, p. 64.
- Blair, W. P. and Raymond, J. C. "Optical and UV Spectra of Supernova Remnants in M33", BAAS, 16, 925.
- Blair, W. P. and Raymond, J. C. "Supernova Remnants and the Carbon Abundance in M33", in Future of Ultraviolet Astronomy Based on Six Years of IUE Research, J. M. Mead, R. D. Chapman and Y. Kondo, Eds., p. 103.
- Cox, D. P. and Raymond, J. C. "Preionization-dependent Families of Radiative Shock Waves", Ap. J., submitted.
- Dupree, A. K., Sonneborn, G., Baliunas, S. L., Guinan, E. F., Hartmann, L. and Hayes, D. "Betelgeuse at Maximum Luminosity", Future of Ultraviolet Astronomy Based on Six Years of IUE Research, (ed. J. M. Mead, R. D. Chapman, and Y. Kondo), 1984, NASA Conf. Publ. 2349, p. 462.
- Hartmann, L., Huchra, J. and Geller, M. "How to Find Galaxies at High Redshift", Ap. J., 287, 487.
- Hartmann, L., Jordan, C., Brown, A. and Dupree, A. K. "On the Outer Atmospheres of Hybrid Stars", Ap. J., submitted.
- Raymond, J. C. "P Cygni Profiles in HL CMA", in Future of Ultraviolet Astronomy Based on Six Years of IUE Research, J. M. Mead, R. D. Chapman and Y. Kondo,

Eds., p. 301.

Raymond, J. C. "New Insights into Degenerate Stars and Interacting Stellar Systems", BAAS, 16, 1011.

Raymond, J. C. "Observations of Supernova Remnants", Annual Reviews of Astronomy and Astrophysics, 22, 75.

Raymond, J. C. "Stromgren Trails of Hot White Dwarfs", in IAU Colloquium No. 81, The Local Interstellar Medium, Y. Kondo, F. Bruhweiler and B. D. Savage, eds., p. 311.